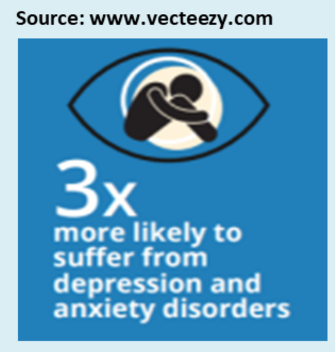
IVY - INTELLIGENT VISION SYSTEM FOR THE VISUALLY IMPAIRED

An Innovative AI-Based IVY System Architecture that includes a Low-Cost Eyeglasses, an Instantaneous Guidance System (IGS) with Vibration Feedback, a Bi-Directional Audio Communication, and a User-Friendly Smartphone App to Assist and Empower People with Visual Impairment to Safely, Confidently, and Independently Maintain Mobility, having Far-Reaching Impact on their Quality of Life

Introduction : Problem

- An estimated 253 million people are visually impaired worldwide.
- Unable to move around safely without human assistance due to:
  - the complexity of finding path
  - avoiding obstacles
  - risk of losing balance
  - fear of falling
- Current methods of environmental and behavioral interventions are ineffective.
- Resulting sedentary lifestyle can significantly deteriorate their quality of life, including adverse physical and mental health.

Source: www.vecteezy.com



Source: www.who.int/blindness

Problem: Visually Impaired people are unable to safely, confidently, and independently move around their homes and other places they regularly visit such as family/friend's home, doctor's office, shopping center etc.

Introduction : Engineering Goal

- Current Electronic Travel AIDS (ETAs) for the blind and the visually impaired do not meet the six most important requirements of an effective ETA for navigation and mobility:
  - Navigation includes identifying and communicating travel pathways, names, and locations of destinations to user
  - Mobility includes detection of obstacles from ground level to height of head, precise location of obstacles along travel path, and identifying and communicating obstacle avoidance instructions.
- Technologies such as ultrasonic, radar, and optical vision have been researched but no suitable aid has yet been materialized.
- Electronic glasses such as IrisVision, Acesight, NuEyes, and eSight, cost up to $6000; are limited to stationary activities such as watching TV, reading, etc. and provide no user assistance in navigation and mobility.

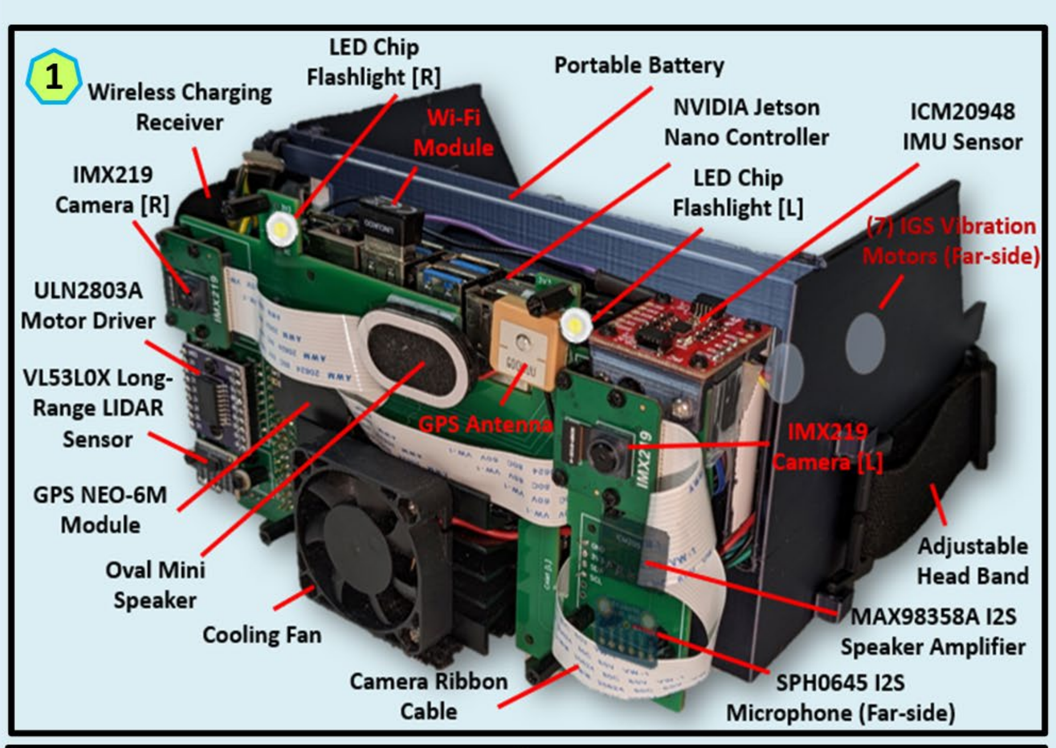
Engineering Goal: Create an innovative AI based Intelligent Vision sYstem (IVY) architecture that includes a low-cost eyeglasses, an instantaneous guidance system (IGS) with vibration feedback, mapping and navigation, object detection and avoidance algorithms, and a bi-directional audio communication infrastructure to assist and empower people with visual impairment to safely, confidently, and independently maintain mobility.

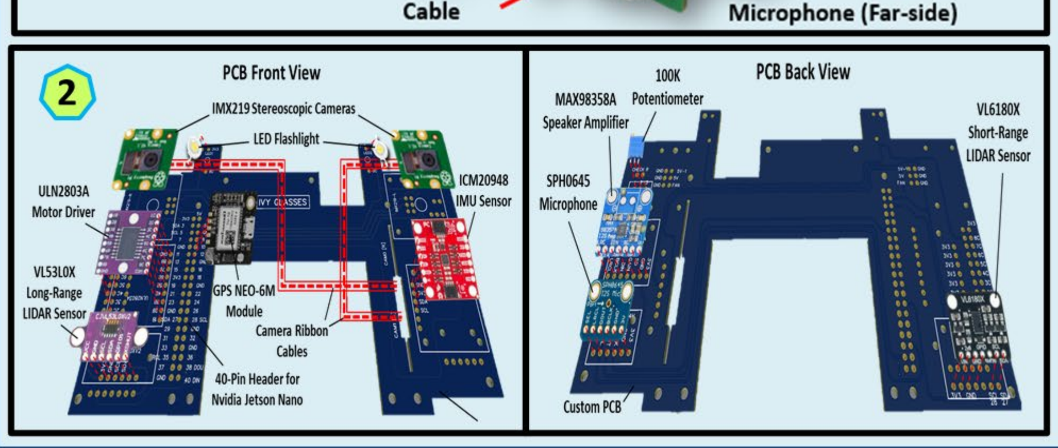
PROJECT METHODOLOGY

Phase 1	Phase 2	Phase 3	Phase 4	Testing	Validation
Eyeglasses & Custom PCB	Mapping and Navigation	Object Detection & Avoidance	Smartphone App & Audio Infrastructure	Device Operation Indoors & Outdoors	Positional & Object Localization

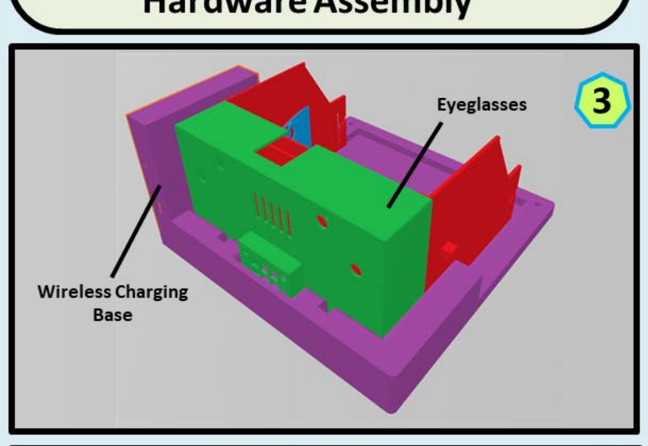
• Design and Assemble Eyeglasses
• Design and Assemble Custom PCB
• Interface Position and Vision System
• Assemble Instantaneous Guidance System (IGS)
• Print 3D Parts
	• Indoor Automatic Mapping Software
	• Outdoor Google Maps API Mapping Software
	• Dijkstra's Shortest Path Algorithm
	• Translating Shortest Path to Voice and IGS Commands
		• Two SSD-MobileNet V2 Object Detection Models (Indoor and Outdoor)
		• Optimized Through TensorRT and Multi-Threading
		• Remapping Navigation Path for Object Avoidance
			• Developed Audio Infrastructure to Communicate with Eyeglasses
			• Voice-Command Interface
			• Smartphone App Supports Initial Setup and Device Testing
				• Device Tested in Five Homes and Five Outdoor Settings
				• Smartphone App + Device Communication for Testing
				• Testing Repeated Three Times for Each Setting
					• Positional Localization
					  • Euclidian Distance Metric
					  • Orientation Angle Difference Metrics
					• Object Detection Accuracy
					• Object Classification Accu.
					• Object Localization
					  • IoU Metric
					  • GIoU Metric

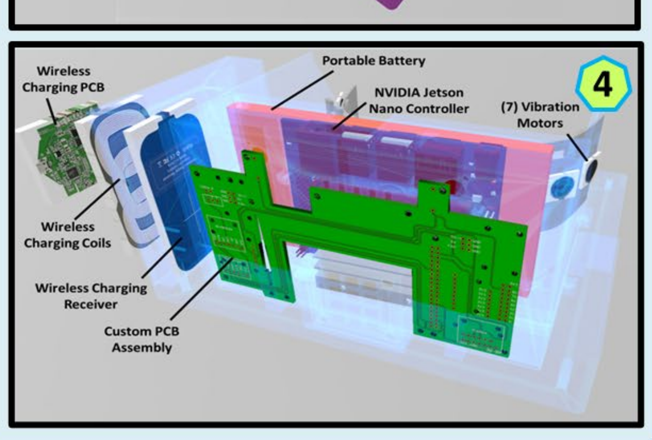
Methods: Phase 1: Eyeglasses & Custom PCB | Phase 2 | Phase 3 | Phase 4





1. IVY Eyeglasses Assembly
2. PCB Design and Hardware Interface (Front & Back)
3. 3D Printed Assembly
4. Wireless Charging and Hardware Assembly

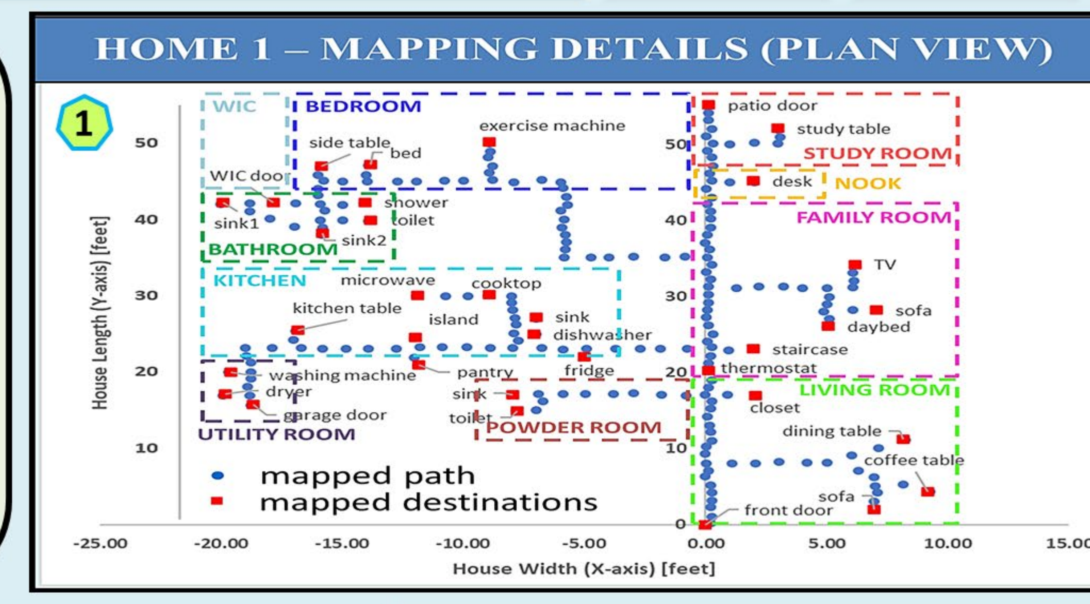




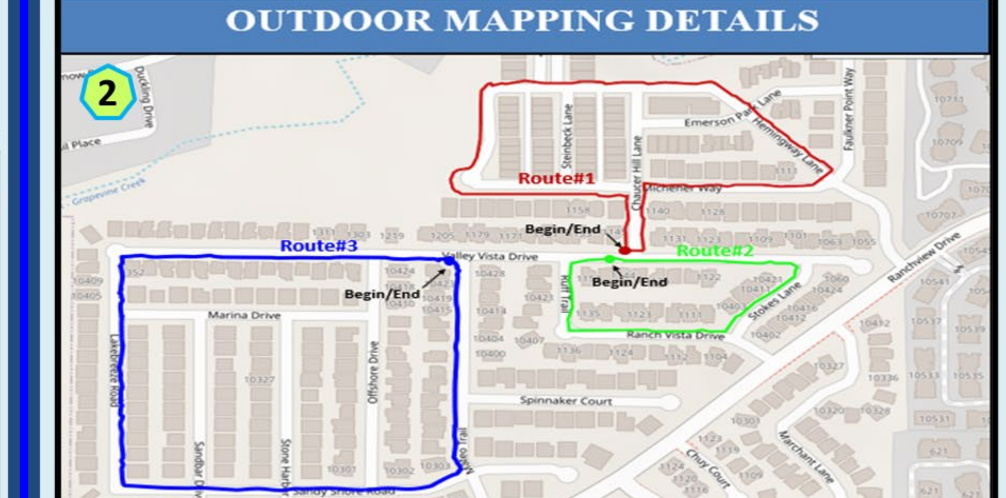
Methods: Phase 1 | Phase 2: Mapping and Navigation | Phase 3 | Phase 4

1. Indoor Mapping of User's Home and Other Indoor Places
2. Outdoor Mapping Algorithm using Google Maps API
3. Navigation Algorithm with Audio and IGS Communications

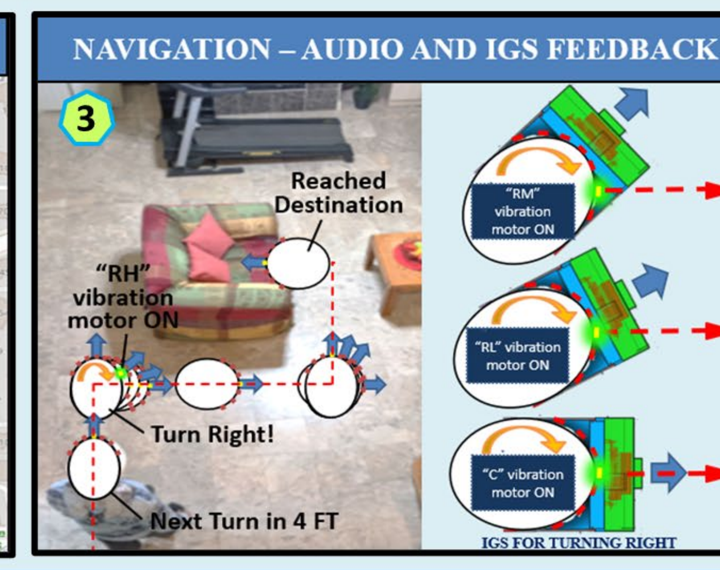
HOME 1 – MAPPING DETAILS (PLAN VIEW)



OUTDOOR MAPPING DETAILS

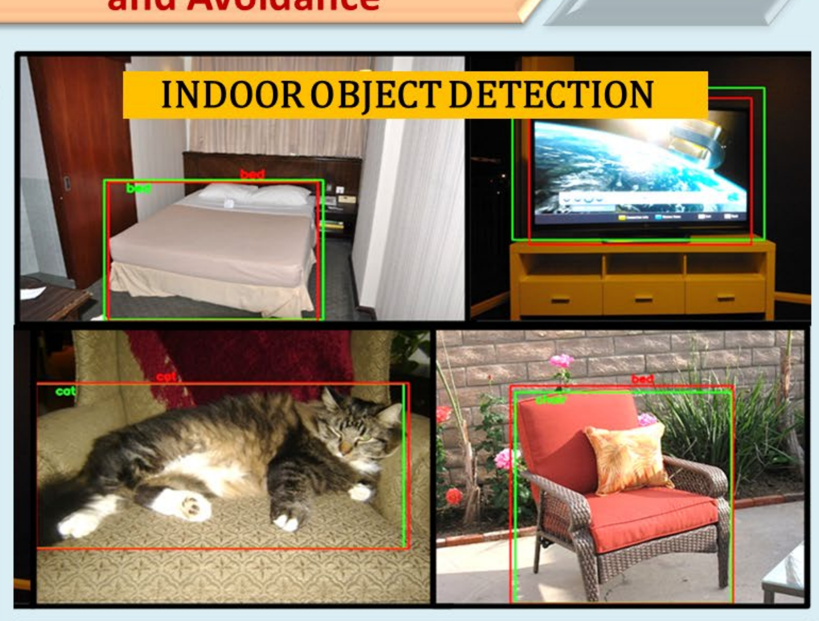


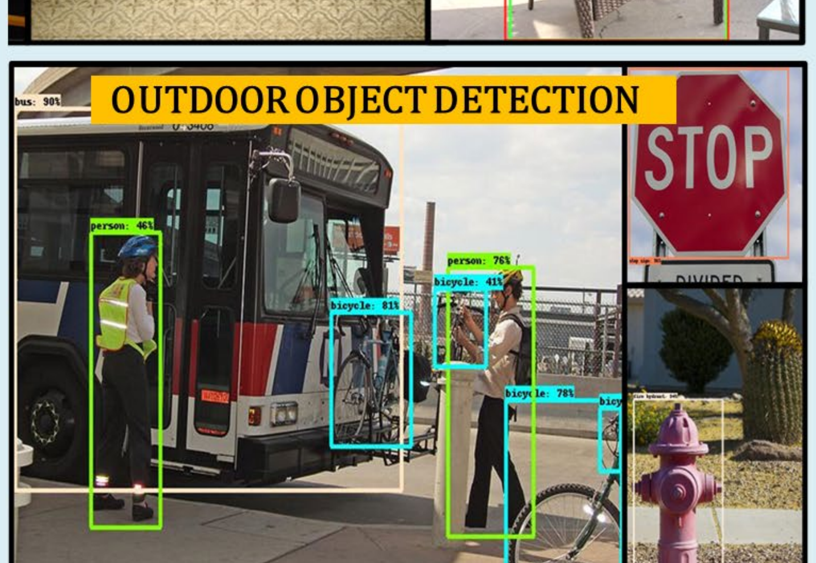
NAVIGATION – AUDIO AND IGS FEEDBACK



Methods: Phase 1 | Phase 2 | Phase 3: Object Detection and Avoidance | Phase 4

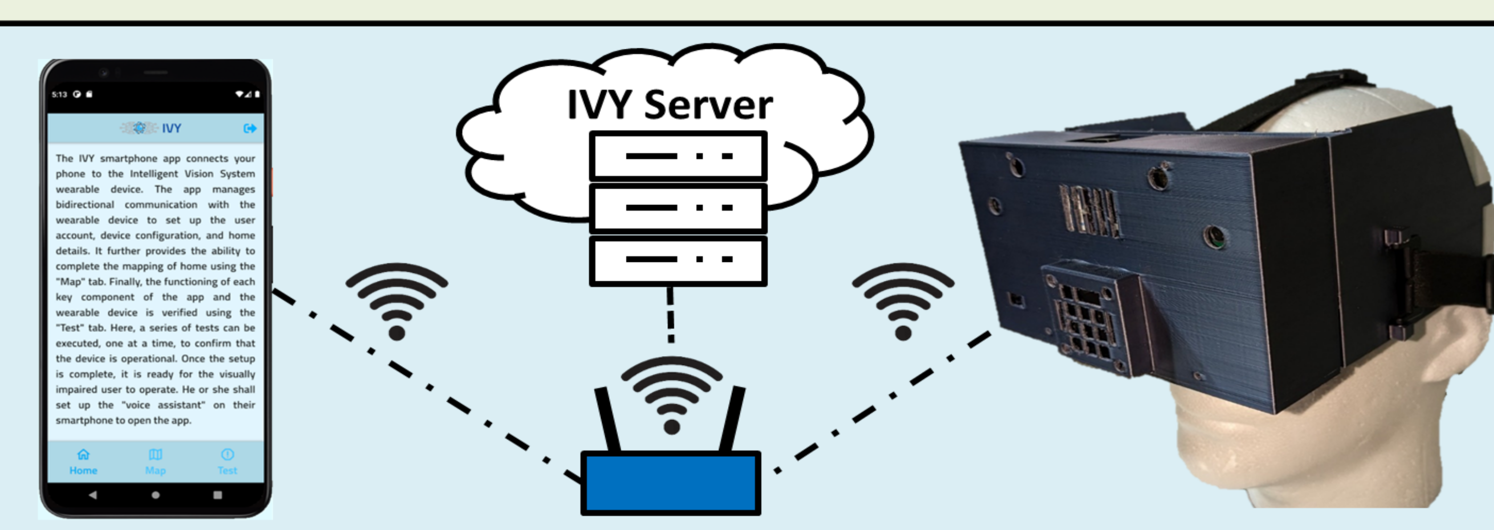
1. Two optimized SSD-MobileNetV2 object detection machine learning models was developed, and object avoidance algorithms were integrated to avoid movable obstacles such as pets, doors, chairs, toys, etc. that may obstruct the user's pathway.
2. The TensorRT platform and multi-threading were implemented to deploy and accelerate the model in the resource-constrained environment of the IVY system.
3. The object avoidance algorithms combine the field of view and depth map of the stereoscopic cameras, as well as the bounding boxes of detected objects to precisely locate obstacles bordering the user's pre-determined pathway, and update navigation instructions accordingly.





Methods: Phase 1 | Phase 2 | Phase 3 | Phase 4: Smartphone App & Audio Infrastructure

1. IVY audio infrastructure was developed to allow the user to bi-directionally communicate with the eyeglass to operate the device without any external aid.
2. The IVY smartphone app supports user saving maps of home and other places they regularly visit such as relative's or friend's home, doctor's office etc.
3. The IVY smartphone app and the eyeglasses both connect to and communicate through a fast and secure Python Flask cloud server, hosted on PythonAnywhere.



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